

Carcinogenic Risk Assessment of Inhaled Lead (Pb) on Batik Industry Workers

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Abstract. Synthetic colorants are still used in process of batik crafting. Heavy metals in colorants, including Lead (Pb) are potential environment pollutants and also hazardous to batik workers as they may expose workers through inhalation route, causing health problems. Lead is classified as probably carcinogenic (Group 2A) based on U.S. EPA (United States Environmental Protection Agency) and IARC (International Agency for Research on Cancer). This study aims to estimate carcinogenic risks of batik workers due to chronic occupational exposure to lead by inhalation exposure route using health risk assessment methodology. Inhalation exposure sampling was carried out using personal sampler pump (type: HFS-513A, flowrate: 2.5 L/min.) with MCE (Mixed Cellulose Ester, Ø25mm, 0.8µm) filter. Filters that retained lead are then analysed using XRF in laboratory. Carcinogenic risk was calculated by determining exposure concentration and IUR (Inhalation Unit Risk) according to Supplemental Guidance for Inhalation Risk Assessment by EPA. It was found that the maximum excess lifetime cancer risk (ELCR) found in all workers is 7.07×10^{-8} , implying acceptable risk. However, risk management is suggested, considering uncertainty and other carcinogens/routes of exposure outside the scope of this study. Actions to reduce exposure are recommended, including providing ventilation or considering outdoor settings to work.

Keywords: batik; cancer; carcinogenic; health; inhalation; lead; risk assessment.

1 Introduction

Heavy metals pollution in environment is caused by human's utilization in many processes. The increase of industrial activities is a factor that causes hazardous materials that may result in heavy metal pollution in environment, as found in wastewater or gas/particulate emission. The presence of toxic heavy metals in environment increases worries about increasing human health risk and environmental impacts.

Batik is an Indonesian cultural textile art heritage. In batik coloring process, both natural and synthetic colorants can be used. However, the use of synthetic

colorants are often preferred for its cheap price and a broad choice of colors to develop more of batik's pattern and design. The textile dyes used in textile industries, including batik production, is possibly carcinogenic [1]. Synthetic colorants used in batik coloring process contain some of heavy metals, such as Al, Ni, Cu, Zn, and Pb [2]. Lead (Pb) is one of five heavy metals that are prioritized to be controlled in public health issues for their high toxicity. Lead may damage various organs in human and cause effects even at small dose, and also classified as probably carcinogenic (Group 2A) based on U.S. EPA (United States Environmental Protection Agency) and IARC (International Agency for Research on Cancer). A toxicology study by Silbergeld & Rice in [3] found the mechanisms of lead carcinogenicity including direct DNA damage, clastogenicity, or inhibition of DNA synthesis or repair. Lead may also generate reactive oxygen species and cause oxidative damage to DNA.

Occupational chronic lead exposure in batik industry workers are likely to occur by inhalation route. The acute and chronic toxicity to textile dyes is caused by oral ingestion and inhalation, especially by exposure to dust/dye dust [4] that might be inhaled. Therefore, lead exposure monitoring on batik workers through inhalation route need to be carried out along with assessment of carcinogenic risk.

Based on the stated background, the objective of this study are to estimate carcinogenic risk of batik industry workers by means of EPA health risk assessment method and to find factors in batik craft work that significantly affect exposure concentration as consideration in risk management.

2 Methodology

Data needed for analysis was acquired through interview (workers' profile: age, sex, working history, working hour). Air sampling was conducted in worker's breathing zone using personal sampler pump to estimate inhaled lead concentration while working. Based on NIOSH 7300 issue 2 in [5], sampling of metals in air may be conducted using personal sampler pump with Mixed Cellulose Esther (MCE) filter Ø 25 mm with pore size of 0,8 µm. Personal sampling pump type used in this study is HFS-513A. The personal sampling pump draws in air around worker's breathing zone, then metals in air will be retained on Mixed Cellulose Ester (MCE) filter. The air flowrate used was 2.5 L/minute and 4 hours sampling was carried out. Pb retained on MCE filters was analysed in laboratory using XRF (X-Ray Fluorescence) method.

Exposure data were then processed to acquire the exposure concentration in accordance with the methodology of health risk assessment. Evaluation of human exposure to heavy metals refers to the Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for

Inhalation Risk Assessment) [6]. Estimation of carcinogenic risks due to exposure is carried out in the risk characterization stage by calculating the ELCR (Excess Lifetime Cancer Risk) for characterizing carcinogenic risk. ANOVA test is used to compare exposure concentration of workers within different groups based on their characteristics and to find significant factors in batik craft work that significantly affect exposure concentration.

These methods involving human subjects has been reviewed and approved by Universitas Padjajaran's Research Ethics Committee, Bandung with approval number: 560/UN6.KEP/EC/2022.

3 Results

Three batik industries were visited and 30 workers were recruited for this study. Batik Industry "SAB", "BS", and "TT" are located near to each other, in Kulon Progo Regency, Yogyakarta. Table 1 below summarizes the characteristics of subjects. The characteristics were found by observation and interview. Other than four characteristics listed below, daily working hour and weekly working day were also asked to subjects. The interview results are needed in risk estimation and comparison across categories.

Table 1 Summary of subject's characteristics.

No	Characteristic	Categories	n (Sample size/people)
1	Origin/Workplace	BS	11
		SAB	10
		TT	9
2	Workplace Condition	Indoor	10
		Semi-Outdoor	12
		Outdoor	8
3	Work Type	<i>Canting</i> (Drawing)	11
		<i>Cap</i> (Stamping)	5
		<i>Celup</i> (Dipping)	14
4	Experience	<3 Years	12
		3-6 Years	11
		>6 Years	7

3.1 Exposure Assessment

Exposure assessment is one of steps in health risk assessment, just before risk characterization. To estimate exposure (the concentration of toxicant, lead in air which is inhaled) on workers, Eq. (1) was used. This equation is recommended

by EPA, as in Supplemental Guidance for Inhalation Risk Assessment Document, Part F.

$$EC = (CA \times ET \times EF \times ED) / AT \quad (1)$$

CA is concentration of contaminant in air, specifically lead. ET is exposure time, the total working hour in a day, assuming that the exposure occurs as long as the workers are working with chemicals (dye). EF is exposure frequency, the total working day in a year, assuming that the degree of exposure are uniform all year long. ED is exposure duration, the predicted of total working years (50 is used). AT is averaging time, the lifetime expectancy in year (70 is used).

By exposure measurement using personal air sampler and interview, EC can be calculated. The result for EC calculation is shown below, in Table 2. EC for all workers are visually shown in a diagram in Figure 1.

Table 2 Summary of EC calculation.

EC	Value ($\mu\text{g}/\text{m}^3$)
Max.	0.0294
Min.	0.00201
Average	0.0143
SD.	0.00767

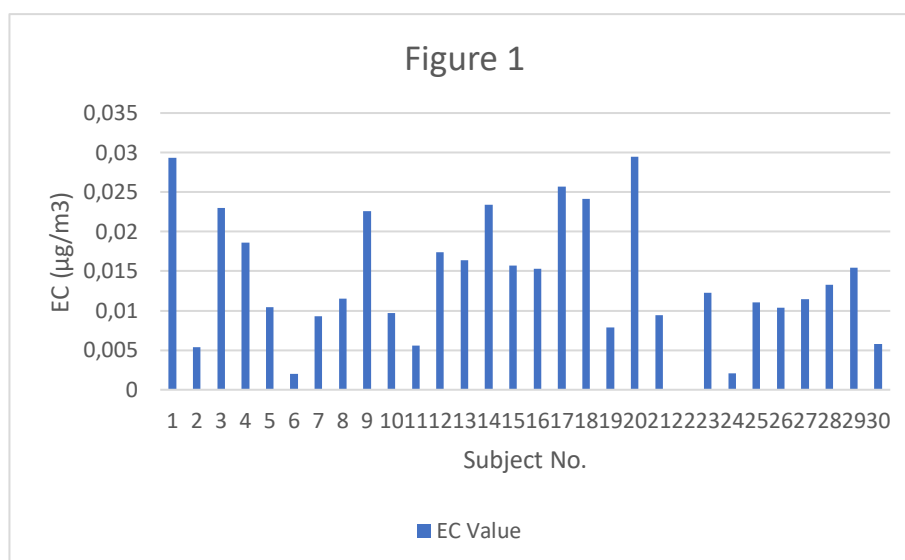


Figure 1 Diagram of workers' EC

The average inhaled exposure concentration of workers is $0.0143 \mu\text{g}/\text{m}^3$ (95% CI, $0.0115 - 0.017$). Values shown in Table 2 are the result of calculating 29 subjects' individual ECs. Subject 22 is excluded for invalid measurement of CA ($0 \mu\text{g}/\text{m}^3$).

and treated as an outlier/measurement error for it is unlikely for a worker to have zero exposure to lead all of the working years and assuming no exposure throughout many working years would be inaccurate.

ANOVA is used to compare exposure concentration across categories of subjects' characteristics as factor, based on Table 1. The results for ANOVA test is summarized in Table 3.

Table 3 Summary of ANOVA test.

Factor	Sig.
Origin/Workplace	0.022
Workplace Condition	0.006
Work Type	0.092
Experience	0.813

ANOVA test on 4 hour-inhalation exposure data, the total inhaled lead (in ng) showed that workers' origin and the condition of the workplace significantly affect the degree of exposure ($p=0.022$ and $p=0.006$, respectively) while work type (drawing, stamping, and dipping) and experience of workers don't. It means that no significant difference in average of exposure was found across categories of work type and experience. 95% confidence interval of exposure degree of each significant factors' categories are given in Table 4.

Table 4 4 hour-inhalation exposure data (mean $\pm$ SD).

No	Characteristic	Categories	Mean $\pm$ SD (ng)
1	Origin/Workplace	BS	25.425 $\pm$ 16.468
		SAB	35.047 $\pm$ 13.385
		TT	16.188 $\pm$ 6.872
2	Workplace Condition	Indoor	31.119 $\pm$ 12.182
		Semi-Outdoor	30.743 $\pm$ 15.458
		Outdoor	11.363 $\pm$ 14.936

It appears that TT industry workers receive the lowest exposure in average, followed by BS industry and SAB industry. This result may be explained by various differences between workplaces, such as differences in craft processes or chemicals used. However, it is known that all three industries are specialized in local batik production which is similar in their whole production processes and chemicals. Therefore, the significant difference is more likely caused by the condition of the workplace. 60% of SAB batik industry workers (highest inhalation exposure average) work in closed room and the rest work in semi-outdoor setting. Meanwhile, in TT batik industry, 66.6% of the workers work in outdoor settings such as garden, and the rest in semi-outdoor setting. This factor might be best explained in the next discussion about workplace condition.

If classification is done by workplace type/condition, outdoor workers (from all three industries) receive significantly lower exposure in average compared to indoor and semi-outdoor workers. This outcome is possibly due to better dispersion on outdoor settings. A recent study about ventilation by Benjamin, et al. related to air change, affect indoor pollutant concentration, such as volatile compound by providing better dispersion, in [7]. A similar result also was found in a risk assessment study by Cupr, et al. in [8] where indoor area scenario poses a higher excess cancer risk than outdoor area scenario. In batik industries discussed in this study, few specific works are done outdoor though not in all industries. When working outdoor with chemicals and dyes, lead in particulate/vapor in air may dispersed better, resulting in decreasing inhalation exposure to outdoor workers, which is favorable. It can be concluded then that outdoor setting is best for batik crafting works related to chemical dye use, whenever possible.

3.2 Risk Characterization

In this part, risk characterization step estimates the risk of exposure to lead based on exposure analysis. The output of this risk characterization is the value of cancer risk. Prior to characterizing carcinogenic risk, the IUR (inhalation unit risk) value was traced to determine the value of cancer risk. The IUR value is usually also determined at the dose-response analysis stage, by conducting research or tracing the results of existing quantitative toxicological studies. IUR used in this study is $1.2 \times 10^{-5} \text{ m}^3/\mu\text{g}$, as in a study conducted by Pavilonis, et al. in [9].

The ELCR (Excess Lifetime Cancer Risk) value is the value of the possibility/probability of developing cancer as a result of exposure to a specific carcinogenic substance and is expressed as an increase in cancer case in an exposed population compared to the unexposed population [10]. Eq. (2) below was used to calculate ELCR. The result for ELCR calculation is shown in Table 5 below, and ELCR values for all workers based on EC is shown visually in a diagram in Figure 2.

$$\text{ELCR} = \text{EC} \times \text{IUR} \quad (2)$$

Table 5 Summary of ELCR calculation.

ELCR	Value
Max.	3.538×10^{-7}
Min.	2.423×10^{-8}
Average	1.713×10^{-7}
SD.	9.208×10^{-8}

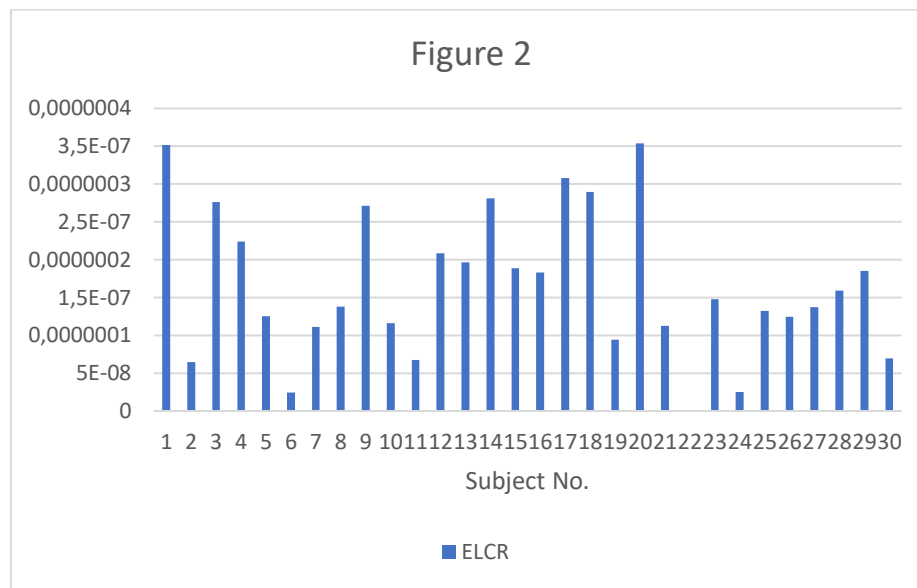


Figure 2 Diagram of workers' ELCR.

it was found that the average ELCR value is 1.713×10^{-7} . If this average value is interpreted, then it is estimated that there will be an increase in cancer cases of 1.7 ~ 2 cases in a population of 10^7 (10 million) people compared to an unexposed population. If the worst case occurs and the highest ELCR value is considered, then it is estimated that there will be an increase in cancer cases of 3.5 ~ 3 cases in a population of 10^7 (10 million) people compared to an unexposed population. In health risk assessment studies, the general accepted ELCR is below 10^{-6} , that is, 1 case in a million people. However, Dankovic & Whittaker in [10] suggested even higher cancer risk (10^{-5} to 10^{-4}) as an acceptable level for occupational setting, considering small number of population, based on review of international policies. It can be concluded that the ELCR found for batik workers in this study is far lower than the maximum acceptance limit. Thus, the carcinogenic risk due to exposure to lead in batik industry is considered acceptable. However, a possibility of underestimated risk due to some uncertainties explained below should be considered.

3.3 Uncertainty & Recommendation

Uncertainties may be classified as qualitative or quantitative. This term refers to a lack of data or an incomplete understanding of the context of risk assessment. Uncertainties in a risk assessment study that affect the accuracy and reliability of this risk assessment need to be stated. The uncertainty in the risk assessment of inhaled lead for batik industry workers is related to the assumptions used.

Assumptions used includes uniformity in exposure degree and negligence of other possible routes of exposure (dermal, oral) and other pollutants/carcinogenic which are outside the scope of this study. Uncertainties can result as underestimated risk as outcome. It is then recommended to consider to reduce exposure to workers, starting from simple regulations or changes, such as wearing face mask when working and consider working in outdoor setting or ventilated room, whenever possible.

4 Conclusion

Risk characterization of inhaled Pb on batik industry workers was done and the result implied that the incremental/excessive lifetime cancer risk is acceptable. Working setting (outdoor/indoor) significantly affects degree of lead inhalation exposure to workers. It is advised to use ventilation to support adequate air change to disperse pollutants in air.

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